THE BENTHIC INVERTEBRATES OF THE BUFFALO NATIONAL RIVER

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Abstract

Macroinvertebrates were collected with a circular depletion sampler at eleven sites along the Buffalo National River during March, June and September of 1982. The organisms were isolated in the lab and identified to the generic level, with the exception of the Diptera, and enumerated. A Shannon-Weaver diversity index was calculated for each site for the three sampling seasons. The genera of invertebrates were placed into general trophic habits and the trophic community structure was described along the river. Ephemeroptera and Diptera were the most dominant orders collected and collectors and collector/scrapers were the largest functional feeding groups in the river. The calculation of the H' index at the generic level did not substantially contribute to the understanding of the community structure and water quality of the Buffalo National River. Although areas of the river may be receiving noticable perturbations, the river, in general, does not appear to be depauperate in the numbers or the diversity of organisms

Introduction

The description of biological parameters of a river system is a good foundation upon which further assessment of water quality can be built. Knowledge of energy flow, type of organisms present, trophic relations, and community structure within a system is essential information used in analyzing the extent of natural or man-induced perturbations. The use of these biotic components of a system rather than physical and chemical parameters has increased in recent years because the organisms are more sensitive to change and are thus better indicators of stream conditions (Karr, 1981).

A basic feature of stream ecosystems is the dependence on introduced, or allochthonous, organic matter for the majority of the energy supply. The allochthonous material is mainly in the form of fallen leaves, needles, twigs, branches, bark, nuts, fruits, and flowers (Cummins, 1974) and is often referred to as coarse particulate organic matter (CPOM). After entering the stream, the majority of soluble organic matter is rapidly leached from the CPOM and enters the pool of dissolved organic matter (DOP). Additionally, microorganisms (bacteria, fungi, protozoans) quickly colonize the surfaces of the CPOM (Cummins, 1974). Eventually, the CPOM is reduced to fine particulate organic matter (FPOM) through physical abrasion, animal feeding and microbial metabolism. The amount of DOM leached from the CPOM and the conversion rate of CPOM to FPOM is dependent on the nature of the CPOM (age and species of vegetation), water temperature, pH, substrate, and flow characteristics of the stream (Cummins, 1974).

There is a continuous gradient of physical and biological variables that change along the river from the small, deep headwaters to the broad shallow downstream area. This is referred to as stream continuum. The narrow headwater area is strongly influenced by the riparian vegetation which reduces primary production (diatoms, algae, submerged vegetation) by shading and contributes large amounts of allochthonous detritus (Vannote et. al., 1980). Hence, this area is generally heterotrophic. As the stream widens downstream and shading decreases, it becomes autotrophic as algae and vascular plants increase in abundance. The downstream areas also receive the FPOM and DOM from the upstream processing of CPOM. It has been hypothesized (Vannote et. al., 1980) that the invertebrate communities along the river, in terms of biomass, conform to these physical continuums since they are greatly influenced by food supply.

When considering the effects of intrinsic and extrinsic factors on the community structure of macroinvertebrates, it is difficult to generalize for all streams. The species composition of a stream community at any place is determined by many independent and unpredictable variables (Patrick, 1975). The response of an organism to a changing variable can be influenced by other local conditions that are acting synergistically. Thus, it is reasonable to conclude that local sampling begets local results.

Of the intrinsic factors influencing the type and number of organisms within a river, current is one of the most important (Hynes, 1970b; Patrick, 1975) since it regulates oxygen and food availability.

Substrate structure, itself defined by the current, provides another important axis along which organisms segregate (Hynes, 1970b; Percival and Whitehead, 1929). Within the substrate profile are microhabitats that are specific for certain orgdnisms in terms of attachment sites, food availability, and oxygen concentration. Downstream drift of stream organisms is another factor that operates, intrinsically or extrinsically, to influence the community of organisms. This dislodging of macroinvertebrates is influenced by light, temperature, flooding, and the size of the organism (Hynes, 1970a). The amount of autochthonous primary production within an area is another intrinsic factor that determines energy flow and the trophic relations within a community.

The dependence on allochthonous material for food is an important extrinsic factor in regulating the type of organisms within a community. In this situation, a heterotrophic community is influenced by the riparian vegetation and the populations of microbes and invertebrates in teh upstream communities. Temperature extrinsically interacts with the quality and quantity of food resources available for a given community and greatly influences the growth cycles of macroinvertebrates. A significant extrinsic factor regulating community structure is the introduction of inorganic or organic pollution. These pollutants act to influence the size distribution of organic particles entering the stream, the timing of the inputs, the cycle of CPOM to FPOM, temperature regimes, primary production, and consequently, the community of organisms (Cummins, 1974; Patrick, 1975).

As man induced perturbations have become more apparent in recent years, there has been an increased interest in establishing water quality criteria. Physical and chemical parameters were widely used to assess water quality because they are easily defined. However, the effects of pollution on these parameters may vary geographically and temporally and may be too subtle to detect (Wilhm and Dorris, 1968). Most improtantly, no knowledge is gained about the response of the biotic community to changes in the physical and chemical characteristics of the water. Since actions of the abiotic environment influence the biotic environment, any perturbation will result in a change in the balance of the community structure. The use of a measurement of the biotic integrity as a criteria for assessing the impacts of perturbations on water quality has increased in recent years (Karr, 1981; Herricks and Cairns, 1982: Wilhm and Dorris, 1968: Hilsenhoff, 1977).

One group of organisms is generally used to indicate environmental quality. In aquatic systems, diatoms (Patricks, 1975), benthic invertebrates (Resh and Unzicker, 1975; Hilsen hoff, 1977; Gaufin, 1976), and fish (Karr, 1981) are most often used for biological monitoring. Though each taxon has its advantages and disadvantages as indicator organisms, macroinvertebrates are well suited because they are numerous, are readily collected, are not very mobile, and generally have life cycles of a year or more allowing for the assessment of past perturbations of short duration (Hilsenhoff, 1977). Additionally, invertebrates are at the lower end of the food chain and thus may be more responsive and sensitive to the early stages of an abiotic change.

Several methods are available to evaluate water quality data when using invertebrates. The oldest, the indicator species concept, calssifies each species in a category (e.g. tolerant, faculative, intolerant) and judges the quality of a stream by the presence or absence of species in each classification. Another method is based on the fact that pollution of a stream reduces the variety of species while increasing the number of only a few species. Using the number of different species and their proportion in the community, several diversity indices can be calculated (Pielou, 1977), the most widely used being the Shannon-Weaver H'. High diversity index values (greater than 3) indicated an unpolluted system composed of moderate numbers of a few species while low values (less than 1) suggest a community of high numbers of a few species, such as would result from pollution (Wilhm, 1970). Of recent interest is the use of a biotic index (Chutter, 1972) to evaluate community structure. With this method each species is assigned a number based on collections in streams of known water quality, ranging from 0 for species found only in clean streams to 10 for those inhabiting extremely polluted waters. The index is calculated by considering the number of each species and their relative proportion in the community. Streams with index values of 0-2 are classified as unpolluted, and through a continuum, values of 7-10 indicate polluted waters.

It is difficult, if not impossible, to consider one of these methods as being the best for evaluating community structure in terms of water quality. All methods have significant drawbacks, the most

important of which is the incompleteness of taxonomic information. A certain method or specific index may be best suited for a given situation yet caution is advised in interpreting the results since the same conclusion is not always reached when using several different methods (Cook, 1976; Godfrey, 1978).

The purpose of this study was to provide an adequate base line inventory of the mocroinvertebrates of teh Buffalo National River (BNR). With this inventory data and selected physical parameters, a description of the community dynamics along with the aforementioned stream characteristics and influencing factors is presented. A Shannon-Weaver diversity index was employed to provide possible insight into the water quality of the BNR. Above all, th~~e~~is study serves as a foundation upon which further specific analysis can be facilitated.

Description of the Study Area

The Ozark province, which includes the Springfield Plateau, Salem Plateau, and Boston Mountains, is separated from the Ouachita province to the south by the Arkansas Valley. Together, the Ozark and Ouachita provinces constitute the Interior Highlands of the United States. The geologic and geomorphic affinities of teh Appalachian Highlands and the Interior Highlands are so great that geologists generally believe the Appalachian Highlands geology and type of structure continues several hundred miles westward beneath the coastal plain sediments to reappear in the Interior Highlands (Thornburry, 1965).

The Ozark Plateau was formed at the close of teh Paleozoic era. Rocks of the Boston Mountains are primarily sandstones and shales of Ordovician and Pennsylvanian ages, in contrast to the carbonate rocks of the Springfield Plateau. Boone limestone, characteristic of the Boston Mountains and of Mississippian age, is nearly pure calcium carbonate ($CaCO_3$), producing caves and sinkholes with red clay and chert often filling enlarged joints and fissures (Branner, 1941; Aley, 1982). Dolomitic sandstone of the Everton Formation and St. Peter Sandstone, along with limestone (esp. Boone), characterize the predominant rock and soil formations of the entire Buffalo River Valley area. Although not considered one of the largest karst areas of the country, the valley contains numerous caves and karst formations.

Originating in the Boston Mountains of the Ozark Plateau, the Buffalo River is a free-flowing body of water approximately 238km

in length located in northwest Arkansas in the counties of Newton, Searcy, and Marion, west to east, respectively. The river winds through the Boston Mountains for nearly two-thirds of its length (direction NNE to ENE) before traversing the lower southeast portion of the Springfield Plateau (ENE) where it converges with the White River (NNE). (Fig.1).

Discrete groundwater recharge zones (e.g. sinkholes, losing streams, and numerous spring systems), occur in the Boone formations of the area, channeling water to the vast underground water transit conduit system which underlies the entire area (Aley, 1982). This groundwater system along with the aforementioned rock and soil formation facilitates a very rapid vertical and horizontal movement of the annual rainfall (especially heavy localized thundershowers).

The Buffalo River is capable of tremendous waterflow at flood stage. Neither naturally occurring nor man-made dams exist on the river. Data examined from 31 years (1950-81) of recorded discharge readings from the United States Geological Survey (1981) at St. Joe, Arkansas, and 20 years (1950-70) at Rush, Arkansas, indicate a mean annual discharge of 26.88m^3/sec (max=1127.87m^3/sec, min=.24m^3/sec) and 34.52m^3/sec (max=1589.79m^3/sec, min=.34m^3/sec), respectively. The largest recorded flood occurred December 3, 1982. On that date the St. Joe gauge broke at 6:00 A. M. and the estimated discharge reported was 3519.54m^3/sec.

The river has a moderate to steep gradient (3.2m/km) associated with its headwaters (~51.52km) and a shallow gradient (.9m/km) associated with its mouth and confluence with the White River. The river

is narrower (24.5m) nearest the headwaters and generally widens towards its mouth (45.5m). The mean length of the pool area (Whisenant, in preps) (fiffle-pool-riffle) is shorter in the headwaters (210m) and generally lengthens towards its mouth (1600m). (Fig.2).

The river is nearly free of any man-influenced perturbations. However, the tributaries which flow into the Buffalo, as well as two locations on the river itself (Boxley Valley area and ~~Tyler Bend~~ Woolum/Bear Creek areas), contain a moderate to large amount of cattle grazing. In some areas, e.g. Boxley Valley, the riparian zone is nearly non-existant, with cattle having direct access to the river. Similarly, the tributaries that flow into the midsection of the river have a large amount of cattle grazing and denuded reparian zones associated with them. Although the Park Service is responsible for ensuring that cattle have no access to other areas of the river, numerous reports of 'trespass' cattle occur each year (and very likely many more go unreported) (pers. verif.). A second perturbation to the river occurs as teh result of canoe usage by the many people who frequent the river for float trips. Finally, it has been reported (Schmitz, 1973) that businesses operating in the town of Jasper (and possibly others) dump raw sewage into the Little Buffalo River, which enters the Buffalo River between the Leypolt and Carroll Place.

Materials and Methods

Sampling was conducted during March, June, and September, of 1982. Eleven sampling sites were located on the Buffalo National River and one was located on a tributary (Calf Creek) near the middle of the river. (Figure 3. and Table 1.). Although access to the river is very limited, these locations were selected because of previous familiarity with them and the plausibility of comparing our results with a bass fishery study that was conducted at the same sampling locations (Whisenant, in prep).

Eight samples were taken from each of the eleven sampling locations along the Buffalo National River during each of the sampling periods. Four samples were taken directly behind the upstream riffle (top of the pool) and four samples were taken directly in front of the following downstream riffle (behind the pool). Because of our intentions to separate the sampling periods by seasons, the decision was made not to sample Tyler Bend and Spring Creek locations during March as the water temperature had risen markedly and personnel, weather, and time were influencing considerations.

Five samples were taken from the Calf Creek tributary. Three samples were taken behind the upstream riffle and two samples prior to the following downstream riffle. The limited size of the area restricted our efforts to obtain eight samples at this location.

Samples of the macroinvertebrate communities were obtained by employing a modified Circular Depletion Sampler (CDS) (Carle and Maughan, 1980) (Figure 4.). The overall height of the CDS is 58.6 cm. The inside circumference and the total sampling area are 184 cm and .33 m^2, respectively. The collecting nets are made of 363 micron nylon (Nitex), retaining even the smallest organisms.

The CDS was forced into the substrate with a turning motion while applying downward pressure until the penetration ring was from 5 to 10 cm into the substrate. The sampling area was continuously agitated with the hands to a depth of 10 to 20 cm for one minute. After the water had cleared, the collecting net was cleaned and all netted material directed into the collecting jar. The jar was lifted out of the water and removed from the CDS. A second jar was then attached and the procedure repeated until two more subsamples were taken. The three subsamples were combined, labeled, and preserved in 5% aqueous formalin.

After each sample was obtained and the CDS removed, we recorded the velocity and depth of each sample with a Teledyne Gurley meter. Water temperature was recorded with a LaMotte Chemical Thermometer Model 1066. Water samples were collected in .5 liter plastic (polyethylene) containers and pH determined in the laboratory with a LaMotte Chemical pH Meter Model HA1906 with pH Electrode Model 1904-S.

Substrate composition of each sample was recorded after the CDS was removed, percentage of each six possible categories; sand, gravel, stones 1-5 cm, 5-10 cm, 10-20 cm and greater than 20 cm were recorded in the field and converted to a weighted average substrate index and a Shanon-Weaver H' diversity index.

Because of the very large numbers of organisms, we subsampled each sample. A circular revolving subsampler developed by Waters and modified by Herricks (pers, comm.) was employed. The confidence of the subsampler has been substantiated by Karr (pers, comm.) and Herricks. The circular sampler is divided into eight separate and removable containers. With a water funnel situated on a 45^{0} angle above the containers, water flows

into the bottom of the funnel and out into the eight containers as they revolve. With the water flowing, the sample was emptied into the funnel so that the heavy sediment and debris settled to the bottom of the funnel and the organisms were displaced evenly into the eight containers. Three of the eight subsamples were randomly selected, combined, and preserved in 70% Isopropyl Alcohol.

Each subsample was placed into a white enameled dissecting tray and the organisms were removed for indentification and enumeration. Organisms were identified to the generic level with a 30x Bausch and Lombe stereomicroscope and with the use of the taxonomic keys in Merritt and Cummins (1978); Brigham et. al. (1983), Usinger (1956), and Huggins et. al. (1981). Identification of organisms was verified by taxonomists at the Illinois State Natural History Survey, Champaign-Urbana, Illinois (ISNHS), and Kansas State Biological Survey (KSBS), Lawrence, Kansas. Vouchered specimens have been deposited with the ISNHS, KSBS, and the Buffalo National River museum.

Results

The number and type of organisms collected at each of the twelve sites for the three sampling periods is summarized in Tables 2-4 . It is not unusual for uncontrolled biological field data to be nonrandomly distributed (Herricks and Cairns, 1982) and most of our data variables followed this trend. Therefore, nonparametric statistics were employed to analyze the distribution and the relationship between variables. Procedures for Spearman's rank correlation (r_s) and the Kruskal-Wallis H-test were followed as outlined by Ghent (1974) and Zar (1974). Critical values were obtained from specially designed tables for low sample sizes (Zar, 1974).

There was a significant negative correlation between the mean weighted average substrate index (WASI) at a site and river distance for March, June and September ($r_s = -.817$, $.02<P<.01$, $n=9$; $r_s = -.827$, $.001<P<.002$, $n=11$; $r_s = -.854$, $.005<P<.01$, $n=11$). (Figure .). The mean substrate diversity index (H'_s) was also negatively correlated with river distance for June and September ($r_s = -.736$, $.01<P<.02$, $n=11$; $r_s = -.763$, $.005<P<.01$, $n=11$). There was a significant increase in pH down river for March and September ($r_s = .874$, $.01<P<.02$, $n=11$; $r_s = .875$, $.001<P<.002$, $n=11$). ~~(Figure .)~~

The total number of organisms collected at the sites during the three sampling periods combined is illustrated in Figure 6 . The total number of organisms collected was correlated with river distance ($r_s = .833$, $.005<P<.01$, $n=9$). The total number of organisms collected at a site for each of the sampling periods is illustrated in Figure 7 . There was a significant positive correlation between number of organisms collected at a site and river distance for June and September ($r_s = .673$, $.02<P<.05$, $n=11$; $r_s = .809$, $.005<P<.01$, $n=11$).

For the September samples only, total number of organisms at a site was positively correlated with pH and negative correlated with temperature $r_s = .648$, $.02 < P < .05$, $n=11$); $r_s = -.759$, $.005 < P < .01$, $n=11$).

The use of the mean WASI, the mean H'_s, and the mean velocity at a site for a sampling period did not yield any significant correlations with the number of individuals or with the organism diversity index (H'_o). Analysis at the sample level, however, resulted in a significant negative correlation between the number of organisms and WASI during June and September ($r_s = -.318$, $.002 < P < .005$, $n=92$; $r_s = -.394$, $P < .001$, $n=93$). Number of organisms and H'_s were negatively correlated for all three sampling periods ($r_s = .324$, $.002 < P < .005$, $n=77$; $r_s = -.376$ $P << .001$, $n=93$; $r_s = -.453$, $P << .001$, $n=93$). For September only, the number of organisms collected was positively correlated with velocity ($r_s = .513$, $P << .001$, $n=93$) and the H'_o was positively correlated with WASI ($r_s = .207$, $.02 < P < .05$, $n=93$).

For a description of the general macroinvertebrate fauna of the river during the three sampling periods, the data were described and analyzed at the ordinal level. The percent composition of the nine orders present during each of the sampling periods is illustrated in Figure 8 . The percent of the community at the eleven sites on the Buffalo National River attributed to each order and the distribution of each order along the river is illustrated in Figures 9 thru 17.

Since life history strategies may cause patterns in order abundance, a Kruskal-Wallis H-test was used to determine if the number of organisms within an order differed between the three seasons. The number of Trichoptera, Coleoptera, and Ephemeroptera were each significantly different between seasons. ($H = 13.36$, $.005 < P < .001$, $k=3$; $H=14.39$, $P << .001$, $k=3$; $H=20.168$, $p < .001$, $k=3$). Only the number of Trichoptera was significantly correlated

with river distance (r_s= .7, .02<P<.05, n=11) and with the mean H'_s (r_s= -.681, .02<P<.05, n=11) for September only.

To better describe the invertebrate community at a site and for the river, each genus was placed in a trophic level using the listing of Merritt and Cummins (1978) and Brigham et.al. (1982) (Table 5 .). When a genus contained species that occupied more than one trophic habit, the genus was given a combined habit description (e.g. collecter/scraper). Diptera were excluded in these analyses since they were identified only to family. Only those trophic levels that contributed at least 5% to the community structure were used in statistical analysis and graphing. The percent that each trophic level made up of the total number of organisms classified into trophic levels for each of the three sampling periods is summarized in Figure 18 . The contribution that each trophic level made to the total percentage of trophic organisms for a site and for the river, with a season, is illustrated in Figures through .

Significant only for June, there was a negative correlation between the number of collector/predators and river distance (r_s= -.62, .02<P<.05, n=11) and a positive relationship with WASI (r_s= .682, .02<P<.05, n=11). This trophic level is prdominately composed of Isonychia. The number of collectors was positively correlated with river distance (r_s= .654, .02<P<.05, n=11) and negatively correlated with mean H'_s (r_s= -.695, .02<P<.05, n=11) for September only. There were significant negative correlations between the number of collector/scrapers and the mean WASI (r_s= -.663, .02<P<.05, n=11) and the mean H'_s (r_s= -.618, .02<P<.05, n=11), only for the third sampling period. Mean H'_s was negatively correlated with

number of predators during September (r_s = -.688, $.02<P<.05$, n=11).

For all of the five major trophic classifications, the number of individuals collected on the river differed between seasons: collectors H = 17.63 $P<<.001$, k=3; collector/scraper H = 19.32, $P<<.001$, k=3; scraper H = 7.577, $.01<P<.025$, k=3; predator H = 5.739 $P<.001$, k=3; collector/predator H = 6.53, $.025<P<.05$, k=3).

Discussion

Geophysical

Employment of the mean substrate diversity index (H'_s) coupled with the mean weighted average substrate index (WASI) indicate~~d~~s that the narrow headwaters of the river contain a more diverse (heterogeneous) substrate composed of larger particles sizes. The river widens downstream and becomes less diverse (more homogeneous) and is composed of smaller particle sizes, yet this does not appear to be a gradual downstream trend. The headwater reaches are narrow and contain a moderate to steep elevational gradient associated with small pool areas (Figure 2.). Examination of the river's profile (figure 5.) indicates that at ~~the~~ Site 4 Carroll Place ~~Site~~, the substrate markedly changes from a more diverse and larger particle substrate to a less diverse and smaller particle substrate. Therefore, it appears that the only true gradual downstream trend originates near the Carroll Place Site, Although not substantiated by this report, it is possible that the narrow headwaters section with a steep elevational gradient, contains a very rapid flow of water which is capable ~~is~~ of dislodging and moving large particles. As these larger particles are broken down due to the torrent movement of the water (esp. floods), the smaller particles are deposited in teh area of the river where teh gradient becomes markedly less steep and the river channel widens (above Carroll Place). Additionally, large particles will be restricted from movement into this area where the hydrologic profile limits their occurence.

The headwaters section of the river contains rocks composed of sandstones and shales, the midsection of the river is predominantly composed of dolomite and limestone, and the lower section passes through carbonate rock. As a result of the geophysical characteristics and hydrology (groundwater recharge), the wäter is alkaline and becomes more so (8.2 pH) in the further downstream areas. Similarly, Nix (1975) demonstrated that alkalinity, as well as the divalent metal ions of calcium and magnesium, increased in a downstream direction.

Initially, we expected to record dissolved oxygen (in saturation) at each of our sampling sites; however, after several recordings (which were either at or above 100% saturation) the instrument succumbed to mechanical failure. Previous sampling by Nix (1973,1975), supplemented by U.S. Geological Survey (1981) monitoring at the St. Joe station and the water quality monitoring by Meyer et. al. (1977), indicates that dissolved oxygen is consistently above 7.2ppm (mg/1;$\bar{x}$=9.5) and near or above 100% saturation (81.8 to 155.1% saturations Meyer, 1978). In general, it is very unlikely that the percent saturation of dissolved oxygen is limiting to the macroinvertebrate community.

Our samplings periods of March, June, and September resulted in mean temperatures of 14.3^{o}C (min=12.0, max=17.0,n=9), 23.9^{o}C (min=22.0, max=27.0,n=7), and 21.1^{o}C (min=19.5, max-24.4,n=11). A comparison of our recorded temperatures with previous studies (Babcock et. al., 1978) and for the year of our study indicates that we sampled seasonally late winter, late spring-early summer, and early autumn.

Recordings of temperatures for previous years (1956-1981) range from $1^{o}C$ (January; U.S.G.S., 1981) to $30.9^{o}C$ (July; Babcock et. al., 1978), serving to illustrate that the Buffalo River is characteristically a warm water river.

General Organism Trends

The life histories of most North American species of aquatic insects is poorly known or unknown. In many cases certain species may have individual populations with highly variable life cycle (exp. Trichoptera; Unzicker et.al., 1982). To understand the factors that influence a species occurence (or lack of), we must have descriptive evidence of a species life history strategy for that particular geographical loaction if we are to interpolate certain biological trends from our data. Therefore, it is apparent that only generalizations concerning community structure and organism trends can be made. Further, caution must be exercised when examining data that has been described only to the generic level. A complete and thorough understanding of water quality tolerances can only be achieved at the species level (Resh and Unzicker, 1975).

For all three sampling periods combined, the total number of organisms captured increased in a downstream direction; however, considering each sampling period individually, we obtained a statistically significant correlation with total organisms captured and river distance for only the June and September sampling periods. It is very probable that the downstream increase in organisms is influenced by several factors operating synergistically.

Aquatic insects are known to partition themselves in relation to certain physical characteristics of the substratum (including the presence of mosses and algae(, and food availability. Substratum and food availability are foten influenced by water velocity and extrinisc and intrinsic nutrient dynamics in both heterotrophic and autotrophic stream ecosystems. Considering the significant correlation between the WASI and river distance, we can suggest that macroinvertebrates are selecting a habitat at least

in relation to smaller particle size in a downstream direction (Figs. 5 & 6).

Further, the significant correlations between river distance and the total number of organisms capture, as well as the significant correlation between the total number of organisms captured and the substrate diversity index (H'_s), suggests that more organisms occur in a homogeneous substrate consisting primarily of small particles which increases in a downstream direction.

A more heterogeneous and/or larger particle substrate generally supports a more diverse fauna because of the greater diversity of niches (Cummins and Laugh, 1969; Lindsuka, 1942). We found however, no correlations between the organism diversity index (H'_o) and river distance, WASI or H'_s; yet for the September sampling period the correlation between H'_o and WASI missed significance by a value of .001. This suggests that a trend between substrate diversity and H'_o may exist. Because very few correlations were obtained using H'_o with any of our variables, it is possible that the Shannon-Weaver index calculated for organisms identified to the generic level is an insensitive indicator of biological associations. Additionally, the exclusion of Diptera, identified only to family, in the calculation of H'_o may have resulted in erroneous values since this order is of numerical importance along the river.

The differences between total number of organisms captured for each season might be explained by several factors acting individually or synergistically.

Aquatic insects (Ephemeroptera) have been found up to 30.5 cm deep in the substrate of a stream (Coleman and Hynes, 1970), and in certain cases (Poole and Stewart, 1976) Ephemeroptera nymphs have been collected up to 40cm deep. Our circular depletion sampler penetrated from 5 to 10cm into the substrate. Considering only the March sampling

period and the extensive groundwater hydrology of the Buffalo River area, warm subterranean water found in the deeper sections of the substrate might provide a more suitable habitat for these insects to overwinter, and would thus result in the paucity of individuals captured. Depending on how deep an organism penetrates the substrate, the substrate should generally be warmer than the water; this difference possible being even more pronounced during the winter months.

As previously mentioned, life history strategies play an important role in influencing an organims occurence. Many aquatic insects spend thier overwintering months in the egg state, as larvae in the diapause (nonfeeding quiescent) stage, in the pupal stage, or they may continue to develop through the winter. Diapause enable insects to survive stressful situations such as high or low temperatures. Prior to entering the diapuase stage insects may move to the edges of the river, under leaf packs, twigs or logs, thereby reducing the effort required to remain in fast-flowing waters. They may also burrow into the soil on land. Certainly periods of overwintering are stressful events in the life histories of insects and increased mortality during overwintering would cause a reduction in total numbers of individuals captured. Total numbers would again then rise with the mating of the overwintering generation in spring and subsequent recoloniztion of the river substratum by the succeeding generation during the summer.

In general, many aquatic insects display a rather rapid development stage as soon as environmental conditions (water temperature, light, food availability) become favorable in the spring in temperate

regions. Often, development is rapid enough to allow two (or more?) succeeding generations to develop through the warm summer months up to late autumn. Of the total macroinvertebrates (Arthropoda) captured for all three seasons combined, 9% were captured in March, 53 in June, and 38% in the September sampling period. Depending on the life stage (e.g. instar, pupa, etc.) of the overwintering generation, this development can be rapid enough to have facilitated the eclosion of the overwintering generation and subsequent development of the succeeding generation by the time we sampled in June. Similarly, it is very possible we collected a second summer generation in our September sampling period. Although not numerically substantiated in our results, the greatest percentage of all organisms examined were of immature lavaral instars.

In summary, we suggest that the paucity of individuals captured during March can be influenced by any one or a combination of the aforementioned factors involved in life history strategies of aquatic insects, and that the increase in total number of individuals captured for June and September is the result of the development of succeeding generations through the availability of nutrients and associated favorable environmental conditions of the warm summer months.

General Trends of Orders

Generally, Ephemeroptera were one of the more dominant groups collected on the river (Fig. 8), especially for the March and June sampling periods. Diptera were also a very dominant group (consisting primarily of Chironomids) in the March and September sampling periods. During the September sampling period, Coleoptera, Ephemeroptera, and Trichoptera were the most dominant groups collected. The percent composition of the dominant orders (Ephemeroptera, Diptera, Coleoptera, and Trichopera, Figs. 9 , 10 , 11 , 12) to the community of organisms at a site was consistently greater than the percent of their total numbers for the river represented at that site for each sampling period. Plecoptera, Odonata, Megaloptera, Lepidoptera, and Hydracarina were subdominant groups for all three samling periods with the exception of Hydracarina, which approached a dominant grouping for the September sampling period (Fig. 17). Generally:

> "...in very soft waters stoneflies (Plecoptera) and mayflies (Ephemeroptera) are the dominant creatures: in slightly harder waters mayflies and chirnonomids became more dominant; and in very hard water the dominants are usually shrimps, snails, worms, and caddissworms (Trichoptera) with cases." (Hynes, 1974; pp46-47).

Our results (Fig. 8 , Table 2-4, as well as Schmitz' (1975) support Hynes' general conclusion of hard water. One only needs to visually examine the substratum of the Buffalo River as the summer approaches to appreciate the hardness of the water, which is indicated by the enormous numbers of snails. Plecoptera, although dominant in very

soft waters, are also general indicators of cold, lotic (Bauman, 1975), fast current, well oxygenated (Unzicker and McCaskill, 1982, Hynes, 1976), and often non-polluted (Hynes, 1974) stream systems. Generally, the Plecoptera group is composed of individuals that have no respiratory gills though the family Perlidae (the dominant Plecopera family in this study; Tables 1, 3 & 4) has many gills, thus enabling them to extend into warmer waters.

The paucity of individuals for the subdominant groups of Odonata and Lepidoptera might be explained by their habitat selection. Most Odonates prefer vegetation (Huggins and Brigham, 1982) and are more frequently found clinging to roots and other submerged vegetation. Since the areas where this vegetation grows were not sampled, the Odonata group is poorly represented.

Similarly, aquatic and semiaquatic Lepidoptera are usually associated with the emergent leaves, stems, or perioles of aquatic or semiaquatic plants (Brigham and Herlon, 1982). More importantly, the Pyralidae family is the exception in that they are found more frequently on rocks in rapid streams where they feed by scraping periphyton from rocks (Brigham and Herlong, 1982, Huggins, pers. comm.). It is not unusual then that we collected only a single genus Pertophila (Pyralidae) of the Lepidoperan group.

It is interesting to note that only with the Trichoptera order did we obtain any correlations at the ordinal level. The number of Trichoptera collected increased with river distance (Fig. 12) and increased with a reduction in particle size for the September sampling period.

This correlation is influenced by the preponderance of Hydropsychid nymphs that comprise the Trichoptera group. Furthermore, Trichoptera are often a major component of invertebrate drift in streams.

> "Population movements are important events in the cycle of caddisflies because they provide a mechanism whereby species can both maintain their densities in a particular area and disperse to colonize adjacent habitats." (Unzicker et. al., 1982)

Examining the total number of Trichoptera collected (Fig. 12) for each sampling period, individually and collectively, reveals a succession of sharp peaks occurring at Steel Creek in March, Carroll Place in June, and Hensely in September. It is suggested that this biological trend is the result of drift.

Trophic Relations

Statements regarding the food habits of aquatic insects are subject to considerable variation and require qualification with regard to habitat and age-specific differences since the majority of species appear to be generalists rather than specialists (Cummins, 1973). Because stream invertebrates have been described according to adaptations for food acquisition rather than food eaten (Cummins and Klug, 1979), the following discussion is organized around the concept of functional feeding groups.

To facilitate the discussion of functional feeding groups on the Buffalo River, a brief discussion of the stream continuum is presented, and a general definigion of each functional feeding group is provided.

The transition from small headwater areas to large rivers is referred to as the stream continuum. Functional and structural attributes of natural stream ecosystems change along this continuum (Karr and Dudley, 1981; Cummins, 1973; Vannote et. al., 1980). Most of the literature has focused on forested watersheds and streams of eastern North America. Considering the geo-morphological affinintíes between the Buffalo River area (Interior Highlands) and the eastern Appalachia Highlands, our discussion of the literature is thus applicable.

Most of the headwater streams in natural watersheds of eastern North America are heterotrophic and dependent on food produced outside of the stream (allochthonous material) (Karr and Dudley, 1981). Generally

these headwater areas contain dense tree conopies which shade the stream so that instream production is minor (Table 6). As the headwater streams give way to larger streams and rivers, the tree canopies are reduced and instream production increases. The increase of instream production usually results from the increased availability of light, which allows for dense populations of macrophytes (mosses) and periphytic algae.

The headwaters area receives CPOM in the form of allochthonous material (detritus). The breakdown of CPOM is accelerated by benthic macroinvertebrates, especially aquatic insects, which ingest and further fragment the CPOM (Karr and Dudley, 1981). Lush and Hynes (1973) demonstrated that the formation of particles in freshwater leachates of dead leaves is influenced by the pH of the water. In an acid water, the rate of formation of particles is much delayed so that much of the potential food is lost to the benthos, but in an alkaline water much of the nutritious material becomes rapidly available.

The downstream area of the river receives FPOM and DOM from the upstream processing of CPOM. Hence, the upstream utilization of CPOM (organic material) provides the downstream communities with a very nutritionally rich food source. Cummins and Klug (1979) suggest that the fragmented well-conditioned CPOM and macroinvertebrate feces probably represent the highest quality of food resource of native stream detritus.

The increased occurrence of macrophytes (esp. mosses), periphytic algae, and submerged vegetation in the downstream area provides locations where FPOM can accumulate. This in turn can provide a substantial

amount of the food resource available for the downstream insect community.

The transition from a hererotrophic area to an autotrophic area is not defined by simple zonation. Often, this transition is very gradual, but can be greatly influenced by abrupt changes such as the clearing of trees and associated riparian vegetation in agricultural areas. Also, the addition of organic effluents into the stream, such as those occurring from cattle grazing, raw sewage, etc., can influence the change from heterotrophy to autotrophy.

The following discussion of trophic relationships is based on the functional feeding group classification of Cummins (1978) and liberally supplemented by the work of Cummins and Klug (1979).

Shredders chew living vascular hydrophyte plant tissue and decomposing vascular plant tissue (CPOM; $> 10^3$ microns) and are thus characteristically associated with small headwater streams (Fig.27). Their occurrence is often related to the autumnal leaf fall, with high numbers occurring thoughout the winter months and a reduction in numbers during the summer months.

Collectors prefer decomposing FPOM ($<10^3$ microns). They exhibit a wide range of morpho-behavioral adaptations for acquiring FPOM and are often (conceptually) separated into filter or suspension feeders and gatherer or deposit (sediment) feeders. Individual insects belonging to this group often construct filtering nets of many varied types and sizes. The type and size of food collected is often concommitant with maturation.

Scrapers generally graze upon (shear off) periphytic algae and associated material (10^3 microns) that adheres to mineral and organic surfaces. Scrapers, along with collectors, generally comprise a large percentage of the dominant insects in medium sized streams (order 4-6). particularly in the middle to downstream areas.

Piercers are adapted through their small size and mouth-part morphology to climb among the strands of macrophytic algae, pierce individual cells or tissues, and imbibe the fluids.

Predators (engulfers) include all macroinvertebrates adapted specifically for the capture of live prey. Generally predators can be collected throughout the year with little variation among total numbers collected.

Based on considerations of stream size, Vannote et. a. (1980) have illustrated some broad characteristics of running water communities which can be grouped into headwaters (orders 1-3), medium-sized rivers (4-6), and large rivers (6) (Fig.27).

In our study, shredders are poorly represented in the June and September sampling periods and moderately represented in the March sampling period (Fig.24,25,26). Considering the time of the year we sampled, it is not surprising to see such paucity. It seems likely that a larger number of individuals would have been captured if we had sampled in December or January when food availability and associated life history strategies were optimal. <u>Allocapnia</u> is generally well represented in this geographical region (Huggins, pers. comm.) and the depauperate representation of this genus is likely due to

our sampling schedule. *Ephemerella* was the only well represented shredder we collected (Fig. 26), yet it is questionable whether this genus is acting as a shredder since certain species of *Ephemerella* are known to feed in other functional feeding groups. We did collect the majority of shredders in the headwaters area and in the March sampling period. If Lush and Hynes (1973) are correct, there might possibly exist a depauperate community of shredders in the Buffalo River as influenced by the rapid rate of particle formations from leachates in the alkaline water.

Collectors were the second largest functional feeding group (trophic level) represented for each sampling period (Fig. 18, 19, 20, 21 25, 26) and for all sampling periods combined. From our significant correlations, this group increased in a downstream direction and where the substrate is homogeneous. Also, the negative correlation obtained with collectors/scrapers and WASI and H'_S suggests that ~~t~~his group is strongly associated with a homogeneous substrate composed of smaller particle sizes. We consider the correlations here to be equally applicable to the collector and scraper groups since we cannot separate the functional feeding strategies of each.

It is interesting that the collector group comprises a very substantial percentage of the community structure even near the headwaters area. Similarly, the collector/scraper group also displays a large percentage of the community structure in the headwaters area. It seems unlikely that the headwaters of the Buffalo River approach a stream order size of 4-6, which would classify the headwaters area

as an autotrophic ($P/R>1$) area dominated by collectors and scrapers (Karr and Dudley, 1981). The Buffalo River appears to approach a stream order size of 4-5. Possible influencing factors for the large percentage of collectors and collectors/scrapers in this area are many, however several can be suggested. If the increased pH (alkalinity; Lush and Hynes, 1973) indeed influences the rapid availability of food particles to this feeding group, the large percentage that they comprise of the community in the headwaters area is not surprising. If we had sampled farther upstream (e.g. Upper Wilderness Area, stretch above Boxley) we may have found an increase in the shredder community and a lower density of collectors and scrapers. This would suggest that the headwaters area may yet be more heterotrophic than our data suggests. However, if the degradation (depletion?) of the riparian vegetation and/or a large influence of organic (nutrient) enrichment, occurring as the result of cattle grazing and/or discharge of raw (untreated) sewage into the river, is influencing growths of macrophytes and periphytic algae, then these perturbations may very well influence the community structure by favoring a food and habitat regimen suitable for thise functional feeding groups.

Scrapers were moderatley represented in the headwaters and downstream areas, with a sparse representation occurring in the midsection of the river. The distribution of the scraper group might have been better described if we had incorporated the Diptera to the generic level since many of the Diptera species exhibit a collector or scraper trophic relationship. Despite the shortcomings of not being able

to include them. we feel that the scraper community is well represented in the river in examination of our collector/scraper group. Together, with the collector, collector/scraper group, and scraper functional feeding groups comprise the dominant functional feeding groups of the Buffalo River.

Analagous to our statement (page 26) regarding each ~~other's~~ orders percent composition to the community of organisms at a site, the collector and collector/scraper functional feeding groups (Fig. 19, 20) percent composition to the community of organisms at a site, is consistently greater than the percent of their total numbers for the river represented at that site for each sampling period. Thus, we conclude that individuals of the collector and scraper functional feeding groups comprise the greater percentage of Ephemeroptera, Diptera (?), Coleptera, Trichoptera orders collected anywhere along the river for each sampling period and all sampling periods combined.

The depauperate representation of the piercer functional feeding group is not surprising. Considering the trophic relationship of this group, imbibing fluids from macrophytes and algae, we may suggest only that we did not collect a larger number because we did not sample in dense macrophyte stands not in periphytic algal mats.

Predators were commonly collected at nearly all sites along the river for each sampling period. Predators expend a great deal of energy in search and capture of their food (living prey). Because of the proteinaceous benefits of consuming living prey and the high

energy expenditure involved in locating prey, it is common to see their total numbers fluctuate synchronously with their relative prey densities, which we believe is demonstrated by our results (Fig.21 , 23).

Considerations for Future Research

Designed to be generally descriptive in nature, this study has provided insight into possible biological trends and water quality of the Buffalo River. With the intention to preserve the naturalness of the river, futher research may be desired. Suggestions for such work are presented here.

A systematic monitoring of both the chemical characteristics and the biological communities would not only provide a better understanding of the dynamics of the BNR but would also serve as a more immediate indicator of change in water quality than would chemical and physical parameters alone. A more thorough biological description of the BNR could also be achieved if the data from this invertebrate study, the fish population study (Whisenant, in prep) and the hydrologic assessment of the BNR (Aley, 1982) were intergrated and analyzed. Certain sites along the BNR may be areas of perturbations as a result of cattle grazing, inflow from polluted tributaries, or high levels of recreational use. The close monitoring of the water quality at these sites is suggested so that water quality degradation can be halted before if jepordizes the quality of the entire river. Finally, any future biological monitoring of the BNR should be done at the species level.

Conclusions

The numerical dominance of Ephemeroptera and Diptera in the river during all sampling seasons is likely associated with the hard alkaline water of the BNR. Trichoptera and Coleoptera were also well represented in the river especially during September. The genera of these orders contributed to the dominance of the collector and the collector/scraper feeding groups along the river. Contrary to the river continuum hypothesis, these two trophic groups were well represented at the headwater area of the river where a greate preponderance of shredders is expected. This may be the result of the denudation of the riparian vegetation and the cattle grazing that occur in this region which serve to reduce the amount of CPOM that is available the the trophic community. The high alkalinity may also cause the CPOM to breakdown quickly, thereby providing suitable sized food particles for the collectors and the scrapers. A trophic community with a lower representation of collectors and scrapers may have been observed in the headwaters if the area above Boxley (the Upper Wilderness Area) had been sampled.

The Shannon-Weaver H' did not change significantly in value along the river and is here considered to be an poor index of water quality. The insensitiviey is likely due to the calculation of the index at the generic level and with the exclusion of the Diptera, which contribute greatly to the river community. Areas of the river may be receiving perturbations from the effects of cattle grazing and recreational use yet it is generally concluded that the BNR is not depauperate in numbers or diversity of macroinvertebrates.

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